FEASIBILITY ANALYSIS REPORT AS TO THE DEVELOPMENT OF A JOINT OPERATIONS INTEROPERABILITY SYSTEM FOR MARINE CORPS C3I SYSTEMS

Topic Number: N90-022

Phase I Final Technical Report

31 May 1991

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13. ABSTRACT *(Maximum 200 words)*

This report provides the final results of the SBIR, Phase I, feasibility analysis into the development of the Joint Operations Interoperability System for Marine Corps C3I Systems. The objective of this effort was to conduct and document an analysis based on the Marine Tactical Systems (MTS) protocol, to determine the feasibility of developing a bi-directional Data Link Interface System that could interface multiple non-MTS digital data link protocols to the MTS protocol, and be readily adapted to changing interface requirements. The conclusion of this analysis was that the development of the Data Link Interface System concept, as documented in this report, was both technically feasible with existing technology, and would drastically reduce the life-cycle-cost of system interoperability.

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1. INTRODUCTION

1.1 Identification of the Problem. Although much effort has been expended to develop interoperability among the services, the situation as it exists today requires each service and agency to implement a large variety of digital data link network interfaces in each of its tactical data systems. The development and maintenance of each of these different digital data link interfaces is extremely expensive and time consuming. In general, each tactical data system is independently developed and maintained causing additional interoperability problems among the tactical data systems due to incompatible versions.

With the current state of computer technology, it should now be feasible to develop a single digital data link network interface module, consisting of hardware and software, that could:

a. Be integrated into any tactical data system,

b. Be capable of interfacing multiple, differing digital data link networks,

c. Be easily adaptable to the mix of digital data link networks interfaced,

d. Be easily adaptable to the variety of data messages implemented and the information needs of the tactical data system,

e. Be easily and inexpensively maintained, and

f. Be responsive to the needs of the operational facilities supported by the tactical data systems.

1.2 Significance of the Solution. The importance of this development would be a significant increase in the responsiveness of any tactical data system to exchange the information necessary to the proper functioning of the operational facility, and a significant decrease in the cost and time necessary to develop and maintain each service or agency capability to interoperate with other services and agencies, and to intraoperate within each service or agency. Upon completion, it is expected that this capability would be rapidly accepted by all services and agencies to provide a significant benefit to the Department of Defense and other departments and agencies.

1.3 Objectives of Analysis. The objectives of this feasibility analysis were:

a. To conduct an analysis, based on the Marine Tactical Systems (MTS) protocol, to determine the feasibility of developing a Data Link Interface System (DLIS) that could interface non-MTS digital data link protocols to the MTS protocol, and be easily adapted to changing interface requirements.

b. To develop a demonstration system to illustrate the feasibility of the DLIS concept.

1.4 Hypothesis of Feasibility. Based on preliminary analysis and experience in the development and implementation of many digital data link protocols, MiTech hypothesized that the Data Link Interface System is not only feasible, but also has the potential to solve many of the existing interoperability problems with a significant cost savings.

1.5 Technical Approach. The MiTech technical approach and concept of the Data Link Interface System functionality is based on an information store-and-forward technique, totally independent of the digital data links being implemented. This allows the system to be extremely adaptable to changing protocol requirements and allows the system to be software configurable to the users needs.

2. DISCUSSION

2.1 Discussion Basis. In order to properly discuss the results of this feasibility analysis, a basic format for discussion must be understood. In order to present a valid discussion the following terms and basic formats are provided:

2.1.1 Information Versus Data. Throughout the discussion of the Data Link Interface System, the terms information and data will be used extensively. To make the discussion understandable, the terms information and data will not be used interchangeably. Information is a "real-world" representation of a fact or presence. For example, the fact that something exists and has a location is really an abstract idea. In order to represent this fact in an information base, the information must be stored in a logical manner that captures the meaning of the information not necessarily comparable to the simple storage of the data that is transmitted or received. If the data received is a relative location, range and bearing, the actual information received is actually the location of the entity being reported. The location of the entity is what is placed in the information base, along with other information that makes the entity location information complete, such as, the effective time information, the identification of the entity, and the uncertainty of the location information. Another important aspect of information storage is that the information may have no direct basis relative to the data being transmitted and received and can be standardized for easy table-driven conversion/manipulation. If the data received is 10 Kilometers (10KM) for a distance, the information stored may actually be 10000, where "Meters" is understood from the information base standardization. This conversion is easy in that the conversion factors maintained in a table need only relate one unit of measurement to the information base standard and the information base doesn't need to store the unit of measure data. Later, regardless of the output protocol, the information can be accessed and if necessary just as easily converted to that protocols requirements, such as "Nautical Miles".

2.1.2 Protocol Model. Throughout this discussion a model of all digital data link protocols will be used. This model allows the discussion to proceed on a generic basis rather than constantly referring to specific protocols. The model selected is the same model used throughout the design plan for the Marine Tactical System (MTS) protocol. This generic model is useful in that every digital data link protocol can be easily transformed into the model through the identification of services and functions. This model consists of the seven-layer International Standards Organization (ISO) Reference Model for Open Systems Interconnection (OSI) with the addition of a 0-layer Transmission Media layer. Table 2-1 provides the organization and services of this model.

DATA LINK INTERFACE SYSTEM (DLIS) REFERENCE MODEL

LAYER 0: TRANSMISSION MEDIA
- Transmission Path

LAYER 1: PHYSICAL LAYER
- Physical Connections
- Data Circuit Identification
- Sequencing
- Fault Condition Notification
- Quality of Service Parameters

LAYER 2: LINK LAYER
- Data Link Connection
- Data Link Service Units
- Sequencing
- Error Control
- Flow Control
- Quality of Service Parameters

LAYER 3: NETWORK LAYER
- Network Addresses
- Network Connections
- Network Service Data Unit Transfer
- Quality of Service Parameters
- Error Notification
- Sequencing
- Flow Control
- Release Service

LAYER 4: TRANSPORT LAYER
- Transport Connection Establishment
- Data Transfer Services
- Transport Connection Release

LAYER 5: SESSION LAYER
- Sessions Connection Establishment
- Session Connection Release
- Normal Data Exchange
- Interaction Management
- Connection Synchronization
- Exception Reporting

LAYER 6: PRESENTATION LAYER
- Data Syntax Transformation
- Data Formatting
- Data Syntax Selection

LAYER 7: APPLICATION LAYER
- Identification of Communications Partners
- Determination of Availability
- Establishment of Authority to Communicate
- Agreement of Privacy Mechanisms
- Authentication of Communicants
- Determination of Cost Allocation Methodology
- Determination of Required Resources
- Determination of Acceptable Quality of Service
- Synchronization of Cooperating Applications
- Selection of Dialogue Discipline
- Agreement on Responsibility for Error Recovery
- Agreement on Procedure for Data Validity
- Identification of Constraints on Data Syntax
- Information Transfer

Table 2-1

2.1.3 Protocol Rule. Throughout the documentation for each digital data link protocol, there are found numerous rules. These rules provide the framework for the protocol, and must be strictly adhered to provide interoperability. These rules exist at every layer of the protocol, are documented inconsistently from protocol to protocol, and unless stated otherwise imply a "no-more, no-less" option. For each protocol, the overall collection of these rules are probably the most difficult to understand and implement, and if implemented incorrectly generate the greatest impact on interoperability.

2.1.4 Field. A data field is the basic syntactic building block of digital data link protocol data. It has a very specific format and generally has a restricted set of valid entries or values. Generally when viewed alone, data fields have no informational value. Examples: Name, Number, Angle, Unit-of-Measure.

2.1.5 Chain. A data chain is a collection of data fields that are related in such a manner that the actual valid entries for the data fields are restricted by the entries in the associated data fields or the informational value is only understood when the additional fields are available. Although on a low-level the data chain provides more information than the sum of its individual data fields. Examples: Date-Time-Group (day of the month is restricted by the month), Range (distance is effected by the unit of measure), Azimuth (angle value is restricted by unit of measure). It should be noted that many times information that could be logically represented by a data chain is represented by a data field and a protocol rule to increase the brevity of the transmission. Examples: Range (only a number is provided - the protocol rule only allows the range in Meters), Azimuth (only a number is provided - the protocol rule only allows Magnetic).

2.1.6 Set. The data set is similar to the data chain and the following data group. The set is a higher collection of related data fields and chains, but provides more informational value than the fields and chains of which it is composed. The set is not used in many protocols as the data group provides a similar and equally satisfactory means of providing information. The set is used to group collections of information together and to allow for optional and conditional fields and chains of information. In many cases the set is used to provide brevity within the protocol documentation. Rather than to restate the same list of fields and chains repeatedly in the documentation, a set will be created, named and thereafter referenced. Example: Emitter-Location (allows various means of providing a location and signifies that the location information is specific to an emitter).

2.1.7 Group. A data group is the next higher logical collection of data. As mentioned above the data set provides a similar capability to provide a collection of related data. The group is composed of multiple fields, chains and sets. As the term indicates the "group" groups related data. The use of the group allows for conditional and optional fields, chains and sets. The group organizes the fields, chains and sets to provide additional information not provided by its related parts. Unlike the set the group is normally allowed to contain multiple subordinate groups. This recursive definition of the group allows a group to provide a collection of groups, thereby providing transmission brevity when used in conjunction with repeatability as discussed below. Although no known use of a group name has been identified, the group could be named and thereafter referenced in the documentation to provide brevity.

2.1.8 Message. A message is the highest order of related data that when viewed as a whole, provides more information than the individual parts. The message generally has a specific purpose in the documentation that also adds information. The message is composed of fields, chains, sets and groups. The message is the highest level of data organization. In some protocols multiple messages can be organized and transmitted together, however, no informational value is added. The simultaneous transmission of multiple messages is used to increase throughput only.

2.1.9 Repeatability. In many protocols repeatable fields, chains, sets and groups are provided to allow for the grouping of data which have some data in common. This repeatability of levels of data provides a high degree of brevity to digital transmissions thereby improving throughput. As a note there are occurrences of repeatability where the whole message is defined as a group and then made repeatable. This is the same as the transmission of multiple messages. Although transmission throughput is improved no additional information can be provided in this manner.

2.1.10 Mandatory. In differing protocols the term mandatory is used inconsistently, however, in general it is used to indicate a need or requirement to provide the data in order to make the information understandable. Mandatory is used with every type of field, chain, set or group data and rules governing this requirement are provided. Again, since rules govern the use of the mandatory classification, these rules are very difficult to understand and implement unless they are strict and allow no exceptions. In some cases the term mandatory is misused when further associated with a subordinate rule, such as, "Mandatory if the information is available" and "Mandatory if assigned". These types of rules actually define an optional use of the data.

2.1.11 Optional. Most protocols provide the capability to skip a field, chain, set or group if the originator of the message desires to not provide the data or if the data is unknown. The rules for not providing data differ significantly from protocol to protocol.

2.1.12 Conditional. Some protocols provide rules that express the use of field, chain, set and group data based on certain conditions. Unlike optional, which expresses an "if known or desired" condition, the truly conditional data usually bases the conditional use of data on another use of data. The designation of conditional fields generally attempts to equate information as experienced in "real-life" to the transmission of data. Many protocols provide no conditional capability, rather depend on the user to understand and equate transmitted data and its informational value. The use or non-use of conditional type data tends to be based on three different audiences. The implementers of a protocol tend to want conditional data, as the rules are easy to understand and they are physically documented. The configuration managers of a protocol tend not to want conditional rules, as the rules are difficult to document and manage. The users seem to fall in the middle wanting the protocol to guide them through the creation of messages, but at the same time not preventing them from changing the conditions. Example: Emitter-Location allows the user to report locations as fixed, circular areas or elliptical areas. If the user indicates a circular area, then only a radius is necessary, however, if an elliptical area is indicated then an orientation, major axis and minor axis is needed. Conditional data provides a certain degree of understanding of the pure data to information conversion thereby assisting in the consistent interpretation of the data.

2.1.13 Fixed-Format. Some digital data link protocols are fixed-format meaning that the fields, chains, sets and groups must appear in a fixed order. Even if a level of data is unnecessary or not used, the positions for the data must appear with some default value. The transmission of unnecessary data creates a sizeable processing and throughput overhead. For this reason few newer protocols use fixed-format messages.

2.1.14 Variable-Format. Newer digital data link protocols are now variable-formatted, meaning that only necessary or available data is transmitted. If data for a field, chain, set or group is not necessary or available, the protocol allows the skipping of that data. Numerous schemes for variable formatting exist for each level of a message, however, the basic underlying intention is that if data is not provided, it is either unnecessary to the understanding of the data, or not available to the message creator.

2.1.15 Character-Oriented. Although all digital data link protocols encode data in a binary (bit coded) transmission, the character-oriented protocols basically transmit all data encoded like the characters of a typewriter. These typewriter characters are then encoded into usually 7 or 8 binary bits. This orientation is based on the use of teletype devices where the teletype directly received the transmission and printed whatever character was represented. The use of character-oriented protocols with computers creates a large amount of inefficiency in the transmission of data. For this reason, few protocols use this orientation except as a last resort for the transmission of free-text data.

2.1.16 Bit-Oriented. By definition all digital data links are bit-oriented due to the transmission of binary signals, however, as used here bit-oriented refers to the protocol not being a character-oriented protocol. The degree of bit-orientation varies from protocol to protocol, but basically the intent is to encode data in as few bits as possible. This greatly increases the throughput efficiency of the data link. If the valid entries for a data field allows only two choices, then this data field is transmitted as one bit. Generally for numeric values the data is transmitted as a binary (base 2) representation of the number, much like the numbers used within a computer. The bit coding of data greatly increases the efficiency of the transmission, however, the processing time for conversion of the data to make it readable by humans increases.

2.2 Hypothesis Basis. In order to properly transform/convert data from one protocol to another, a reference point must be reached where the representation of the data is consistent to both protocols. Although many attempts have been made at interoperability through message format and data format conversion (such as existing Tadil-A and Tadil-B forwarding), this conversion process at the Presentation Layer requires a significant amount of co-configuration management of the two interfaced digital data links to ensure interoperability. Data-to-data conversion requires that the two protocols must generally have a one-to-one correspondence between the valid data values. In the case of the Data Link Interface System, the number, types and specifics about each protocol to be interfaced is unknown as the purpose is to interface multiple protocols and to be adaptable to changing requirements. No co-configuration management of protocols is intended or expected in the development of the Data Link Interface System. As the Data Link Interface System must be virtually independent of data. The result of this initial analysis is that the Data Link Interface System must be based on the very highest layer of the model, the Application Layer, as the lower protocol layers tend to restrict system flexibility.

2.3 Hypothesis. Based on the above understanding of digital data link protocols in general, and many specific protocols currently in use today, the MiTech hypothesis is that the Data Link Interface System concept is feasible and economically practical only if the interface between differing protocols occurs on a "real-world" information level, thereby isolating each protocol from the other interfaced protocols. In reference to the Table 2-1 reference model, this is interfacing the multiple protocols at the Application Layer where Information Transfer takes place. In addition to isolating each protocol implemented, other facets that this concept allows are:

a. The upper layer isolation of a single protocol's input from its output, thereby allowing differing versions of the same protocol to function independently.

b. Since the Man-Machine Interface (MMI) into a digital computer is a digital data protocol, the Data Link Interface System, when used as terminal equipment, could make available multiple host system interfaces as if the system interface was another protocol (a generic user interface).

c. Since the individual protocols are in general already implemented, and the Data Link Interface System interfaces with the individual protocols in the same manner as the current systems, much of the hardware and lower layer software already developed can be readily identified for reuse in the Data Link Interface System. This similarity of function allows a Non-Developmental Item (NDI) or Non-Developmental Software (NDS) approach feasible.

2.4 Data Link Interface System Processing. As depicted in Figure 2-1, the Data Link Interface System is designed to be extremely modular with as much independent multi-processing identified as possible. The Low-Layer Interface Processing modules are primarily responsible for the layer-0 through layer-6 services. They provide the same data specific services for the Data Link Interface System as they currently provide for many other system. Although not depicted these modules must usually interface with each other to control input and output functions. The other processing modules depicted are the actual heart of the Data Link Interface System and are responsible for conversion of protocol data to "real-world" information and "real-world" information to protocol specific data. In addition, the Modification Information Update Processing and Message Generation Processing modules are responsible for maintaining the status of new information received and determining which protocols and messages should be developed and transmitted.

DATA LINK INTERFACE SYSTEM (DLIS)
SUBSYSTEM PROCESSING DIAGRAM
(Not All Read Interfaces Shown)

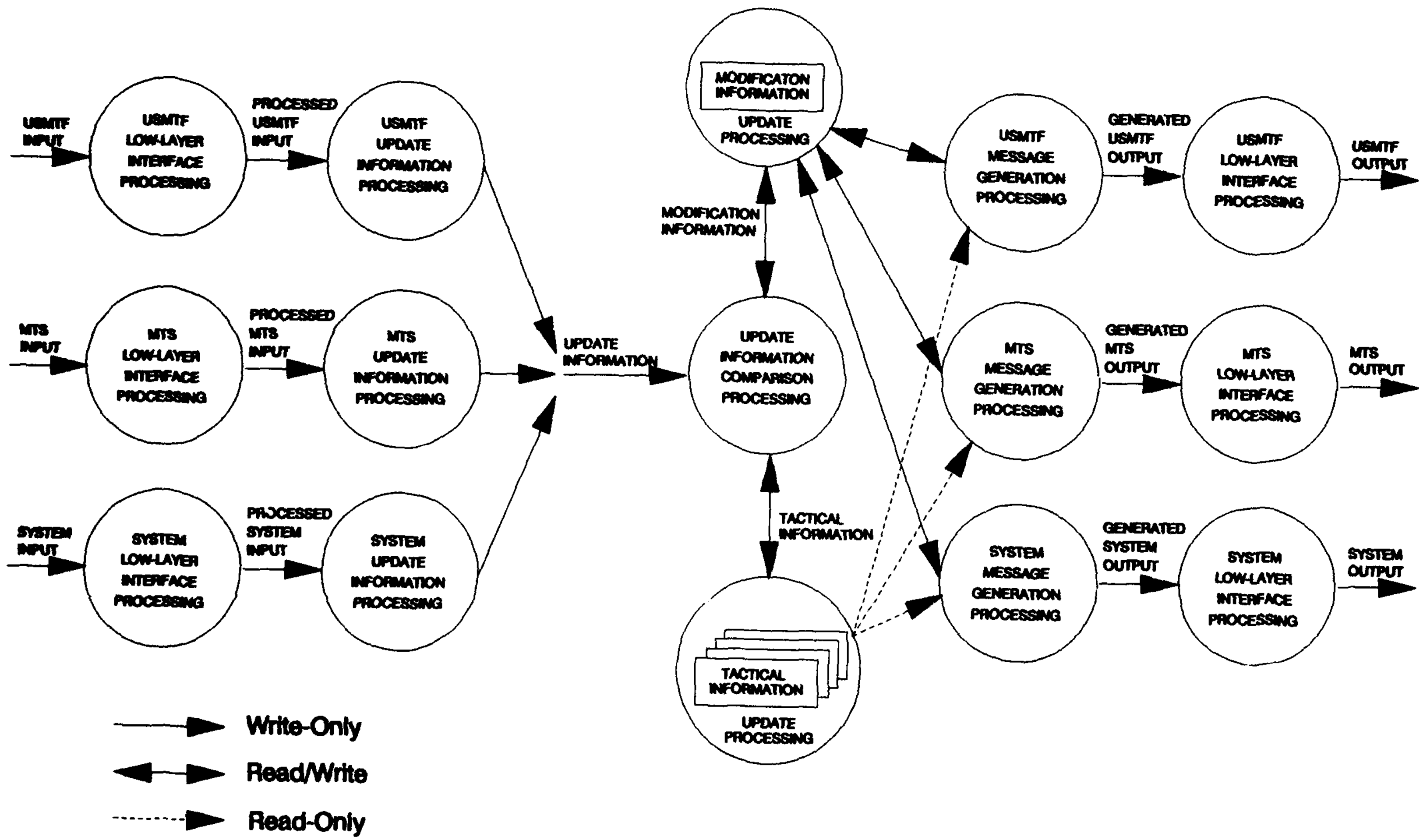

Figure 2-1

2.5 Layer 7 - Application Layer Analysis. As discussed above the feasibility of the Data Link Interface System depends to a great extent on the feasibility of a protocol independent Application Layer. The reasoning behind the determination of feasibility is simple, straight-forward logic.

a. The intent of digital data link communications is to create a pathway whereby one human can exchange information with another human, and upon receipt, the receiving human then has the same information as the sender. The creation and implementation of each data link protocol has the purpose of providing this pathway. Since each protocol is intended to be capable of describing the "real-world" information in digital form and thereby transferring this information to the receiver, the digital description must provide the necessary data to reconstitute the information at the receiver.

b. The exchange of data between humans and computers are all based on digital data protocols. The pressing of a key, the positioning and button press of a mouse, and the finger-on-glass selection from the screen all result in a digital input of data into the digital computer. The output of data to a screen, printer or other digital device are all based on digital data protocols. Any of this digital data could be stored and used to re-enact the stimulus. The redirection of input from a saved file instead of direct input from a keyboard is an example of this capability.

c. From the above, the very existence of digital data link protocols assumes that a human can provide a digital data picture of "real-world" information that can be exchanged. In other terms the digital data provides a representation of the information to be exchanged. The assumption that a human can provide a digital picture of the information has no effect on the feasibility analysis. If a protocol either can't provide the representation or provides an inaccurate representation then the protocol is actually violating its primary purpose. In such a case the modification of the individual protocol to correct the problem is necessary. In many cases the information analysis necessary for the development of the Data Link Interface System may identify many such problems.

d. Since this digital data can be exchanged it can also be stored, thereby saving the representation of the information for future use.

e. Each protocol that exchanges the same information provides a representation (although different) of the same information.

f. If two different representations of the same information exists then there is an inherent capability to convert between the two representations. This alone makes the Data Link Interface System technically feasible. This may be a direct protocol to protocol conversion, or the conversion may require the existence of interim representations. The direct protocol to protocol conversion would require the exponential development of an extremely large amount of software to provide individual protocol to protocol conversion modules and would greatly increase the cost and decrease the maintainability and adaptability of the system. This direct conversion is primarily a Presentation Layer interface discussed earlier and is very similar to the methods currently used in data forwarding, such as Tadil-A to Tadil-B.

g. The hypothesized Data Link Interface System would use the interim representation method to store and convert multiple protocols thereby ensuring interoperability and decreasing life-cycle cost and effort. In order to further increase maintainability and adaptability, the interim representation used within the Data Link Interface System must effectively represent the "real-world" information and should be generally independent of the envisioned protocol interfaces.

2.6 <u>Layer 6 through 0 Analysis.</u> As discussed in the basis for the MiTech hypothesis, the interfacing of the Data Link Interface System at the Application Layer allows the system to reuse the software and hardware already implementing any protocol for services below the Application Layer or if necessary the development process would be comparable to any implementation of the individual protocols. For this reason the feasibility of satisfying the Presentation Layer through Transmission Media Layer service requirements is only hindered by the capability to implement the specific protocol. Since it is assumed that the desired protocols are implementable, the feasibility of implementing the protocol in the Data Link Interface System is fundamental.

2.7 <u>Application Layer Configuration Interface.</u> As with the implementation of any protocol, the system must provide the operator with an interface to provide configuration data necessary to the proper functioning of the protocol. For the Data Link Interface System the configuration data necessary for proper protocol use would consist of a super set of the individual protocol configuration data. In addition, since the purpose of the Data Link Interface System is to provide protocol conversion without operator interaction, the system must be provided with the rules and data, in table form, for control of the generation process. In general this includes identification and correspondence of addressee information, and for each output protocol there needs to be a list of valid messages for that link (which can also be based on the message format in use or rules for complex filtering).

2.8. Generation Process. In order for the Data Link Interface System to be truly feasible, the overall process of protocol conversion must be automated to the greatest extent possible. This automatic generation process must alleviate the operator interaction thereby allowing the system to function as rapidly as possible. The utility of the Data Link Interface System is greatly influenced by the amount of operator interaction desired. The generic generation process is fairly straight forward:

a. If the "real world" information changes, the fact that the specific information changed must be stored (Modification Information),

b. Along with the modification information, the source of the information must be stored to prevent retransmission to the originator,

c. In addition to the modification information, the allowed output protocols must be indicated. This information is usually set during system configuration.

d. The generation processes for each protocol function independently based on the indicators stored in the Modification Information. These indicators tell the generation process when information has been changed and therefore a message within the protocol must be produced.

e. Once the generation process is executed, the process must determine which message or messages must be produced to pass the indicated information as output. This again is determined through the use of preset configuration data, and can be either simple or extremely complex.

f. When it is so indicated that a message must be produced, the generation process accesses (read-only) the "real-world" information base to produce the message if possible. Depending on the protocol requirements, all of the information necessary for a particular message may not be available. If not available the generation process aborts and tries the next possible message.

g. This try and fail process continues until either a message is successfully produced or the generation process has exhausted all possible indicated messages.

h. If a message is produced, the message is output in accordance with the lower layer protocol requirements. Based on the current configuration information, the generation process can then either try to generate additional messages to pass the same information or cease the generation process based on the current data.

i. If no message can be produced, again based on operator selected configuration data, the generation process can cease the generation process or the information can be formatted into a protocol equivalent free-text message, if free-text is supported by the transmitting protocol. The latter is not deemed a wise option as very quickly the receiver of these messages becomes overcome by messages requiring operator attention, as they are human readable only (no automated value).

f. Regardless of the message/messages transmitted the generation process must then remove the modification information indicators so that the generation process can continue to the next updated information. In addition to the removal of the indicator that started the generation process, the satisfactory production of a message may also clear other indicators that are pending service if additional updated information is transmitted in the message.

g. Once all indicated output protocols have removed their respective indicators, the modification information entry can be totally deleted thereby completing all processing necessary for the updated information.

h. As a note, if information can't be transmitted due to the lack of necessary (mandatory) information for a message due to protocol requirements, the message indicators and ultimately the modification information entry are deleted as if a message was generated. This creates no problem as the later receipt of the lacking necessary information will trigger the generation of the message and the unpassed information will be transmitted at that time.

2.9 Feasibility Results. The Data Link Interface System is technically feasible, and provides a low risk, low life-cycle-cost, and highly modular/reusable solution to the interoperability problems currently being experienced by the Marine Corps and the Department of Defense.

2.9.1 Low Risk.

As the Presentation through Transmission Media layer implementation of each protocol is similar to the implementation of the protocol in any current system, the reuse/development of the individual protocols are identified as negligible risk.

As the primary information storage subsystem, modification information storage subsystem and generation processing subsystems are very similar to current command, control and intelligence system implementations, the integration of the Data Link Interface Systems functional core is basically the proper interfacing of the three independent subsystems.

2.9.2 Low Life-Cycle-Cost.

As each current host system is independently developing multiple data link protocol interfaces, the one-time cost of the reusable Data Link Interface System would be comparable to or less than any single implementation of the specific protocols, but provide greater interoperability.

As the Data Link Interface System only interfaces with the host system through a single (or more if desired) data link protocol, the development of the host system can be totally independent of the Data Link Interface System's environment (operating system, database management system, language, hardware). This allows the development and maintenance of the Data Link Interface System to proceed independent of the host systems as long as the individual host system interface is unaffected. In addition this allows the host system to be developed and maintained independent of the types of data link protocols implemented.

As the intent of the Data Link Interface System is to centralize the implementation and maintenance of data link protocols in a single, reusable system, this will allow for one time, centralized maintenance necessary to implement protocol changes. This alone sufficiently impacts the life-cycle-cost of system maintenance to make the Data Link Interface System economically feasible. System specific implementations, as developed today, require a tremendous effort and cost to maintain interoperability, and due to the need for simultaneous introduction of a change to the field, the protocols can only be modified as fast as the slowest system modification. In addition, as the independent host system data link protocols are tightly coupled to the overall system requirements, in general, the modification of the host system makes the use of older versions of the protocols impossible, thereby making backward compatibility to older, exported systems impossible.

3. DOCUMENTATION

3.1 Intermediate Reports

a. Monthly Technical and Fiscal Report No. 1
"Joint Operations Interoperability System for Marine Corps C3I System"
Contract No. DAAL-91-C-0004,CLIN 0002AA
covering the period 1 November 1990 to 30 November 1990 dated 12 December 1990

b. Monthly Technical and Fiscal Report No. 2
"Joint Operations Interoperability System for Marine Corps C3I System"
Contract No. DAAL-91-C-0004,CLIN 0002AA
covering the period 1 December 1990 to 31 December 1990 dated 14 January 1991

c. Monthly Technical and Fiscal Report No. 3
"Joint Operations Interoperability System for Marine Corps C3I System"
Contract No. DAAL-91-C-0004,CLIN 0002AA
covering the period 1 January 1991 to 31 January 1991 dated 14 February 1991

d. Monthly Technical and Fiscal Report No. 4
"Joint Operations Interoperability System for Marine Corps C3I System"
Contract No. DAAL-91-C-0004,CLIN 0002AA
covering the period 1 February 1991 to 28 February 1991 dated 14 March 1991

e. Monthly Technical and Fiscal Report No. 5
"Joint Operations Interoperability System for Marine Corps C3I System"
Contract No. DAAL-91-C-0004,CLIN 0002AA
covering the period 1 March 1991 to 31 March 1991 dated 14 April 1991

3.2 Research Sources

a. Joint Pub 6-04.10 "U.S. Message Text Formatting Program" dated 1 October 1990

b. "Technical Interface Design Plan (TIDP) for Marine Tactical Systems" dated 16 July 1987

4. DEMONSTRATION MODEL

4.1 Demonstration Objective. The second objective of this feasibility analysis was to develop a demonstration model of the Data Link Interface System. For this demonstration the Marine Corps' Marine Tactical Systems (MTS) protocol and the Joint U.S. Message Text Formatting (USMTF) protocol were interfaced as hypothesized.

4.2 Message Formats. The following message formats were used in the demonstration. These messages were selected as they provide the opportunity to exemplify the non-trivial aspects of the Data Link Interface System feasibility.

a. MTS:
- U075 - Free-Text Message
- K403 - Tactical Elint Report (Intell Ops)
- K404 - Tactical Elint Report (Emitter Location)
- K405 - Tactical Elint (Parametric Data)
- K446 - Enemy Sighting (SPOT) Report
- K701 - Position Report

b. USMTF:
- F260 - System Reply/Remarks
- C121 - TACELINT

4.3 Demonstration Functions. The demonstration model developed, as depicted in Figure 4-1 and 4-2, exemplified the following functions:

a. Upon receipt of an MTS message the automatic generation of the proper USMTF messages to transmit the information embodied in the MTS message.

b. Upon receipt of a USMTF message the automatic generation of the proper MTS messages to transmit the information embodied in the USMTF message.

c. Upon receipt of multiple MTS and USMTF messages, the automatic generation of the proper MTS and USMTF messages to transmit the resultant information embodied in the received messages.

d. To demonstrate the feasibility of a host system interface not based on the long-haul wide area network protocols, the demonstration provided an example of a local interface. This local interface was serviced by the demonstration system in the same manner (functions) as the above protocols. Upon receipt of singular or multiple MTS and USMTF messages, the demonstration automatically generated the proper host system communications to transmit the resultant information embodied in the received messages.

DATA LINK INTERFACE SYSTEM (DLIS) DEMONSTRATION SYSTEM

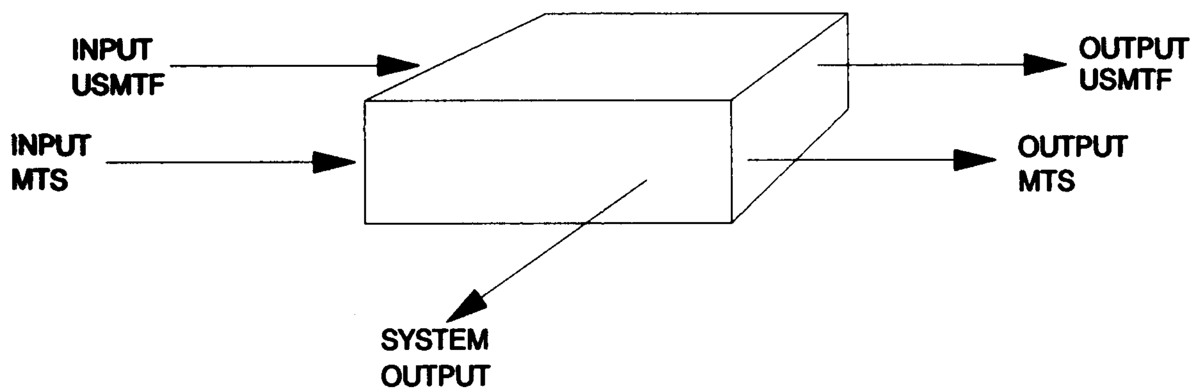

Figure 4-1

DATA LINK INTERFACE SYSTEM (DLIS) DEMONSTRATION SYSTEM

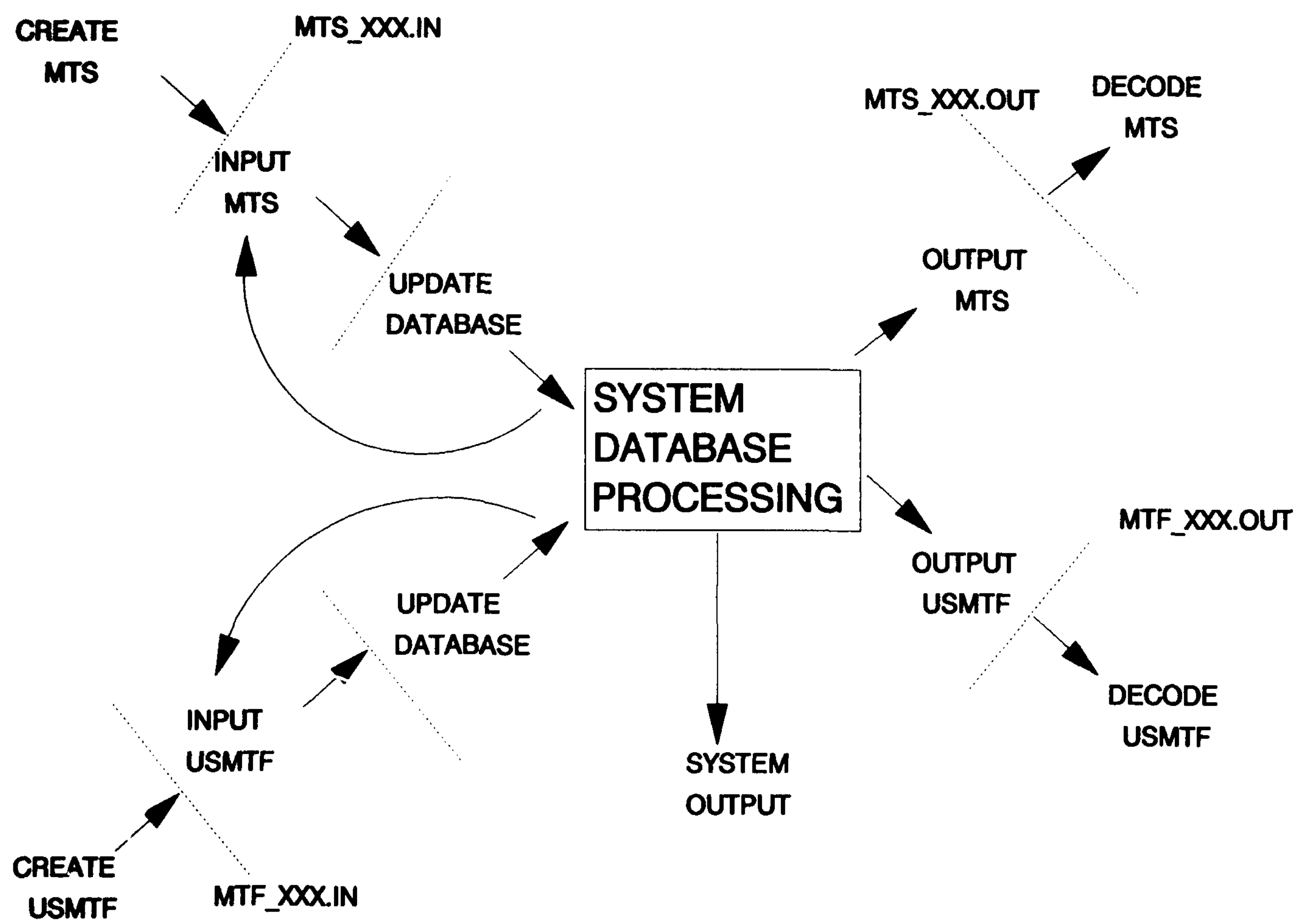

Figure 4-2

e. To demonstrate the feasibility of a interface based on two versions of the same protocol, the demonstration provided an example of an MTS-to-MTS and USMTF-to-USMTF interface. This is similar to an MTS-Broadcast to MTS-Switched protocol interface. Upon receipt of singular or multiple MTS and USMTF messages, the demonstration automatically generated the proper same protocol communications to transmit the resultant information embodied in the received messages.

4.4 Adaptability and Maintainability. Although difficult to demonstrate, the development of the demonstration Data Link Interface System attempted to maximize the use of data-driven processes thereby providing a more adaptable, easy to modify system. As examples:

4.4.1 List Files for Selection Type Fields. In both protocols there are many fields that offer the creator of a message a list of valid entries and the operator selects from this list. In the demonstration system this capability was provided by implementing the lists as data files and using a very small, generic software package to provide the selection capability. In this manner the addition, deletion or modification of valid entries or the addition or deletion of entire lists only required the modification of the data file, no software was effected. These same data files were used in the creation, receive, update and generate processes, thereby providing the capability to centralize the modification of list type fields to the modifications of a single data file entry in a single data file to provide a consistent modification to the particular protocol being modified. These same files also provided the conversion factors necessary for the conversions of units-of-measure between protocols.

4.4.2 Generic Subroutines for Numeric Type Fields. In both protocols there are many fields that require the operator to enter numeric type data. These fields seemed to span the full range of what would be desired in numeric input/output capabilities. This ranged from normal range constraints (0 to 999) on values, to fixed length fields with variable decimal digits (99.999 and 999.99, but not 100.999), fixed length fields with leading integer zeros (0099.99), to complex shifting of decimals prior to output (999.99 -> 99999) and then reverse shifting decimals upon receipt (99999 -> 999.99). This was further compounded by some fields requiring a fixed length field but also allowing the last digit to be a "K" or "M" to indicate units of 1000 and 1 million, but also restricted the ranges allowed based on the use/nonuse of the qualifier. All of these identified formatting conventions had to be taken into account in the demonstration system, and resulted in a set of generic subroutines that provided the desired formatting capabilities based on parameters passed by the calling routine. The use of these generic parameterized subroutines supports the further use of data files for driving message level processes.

4.4.3 Data Files for Chains, Sets and Groups. Although not as obvious as using data files for fields, much of the processing for chains, sets and groups can be data driven. Although not independently driven in the demonstration model, these syntax related protocol rules can be driven by a mix of data files and generic subroutines. In the demonstration model the data driven aspects of these syntax elements were incorporated in the message level syntax processing. They should be handled independently thereby allowing a more adaptable and maintainable solution.

4.4.4 Data Files for Message Formats. As both of the protocols use message formats in the syntactic formatting of the data to be transmitted, these message formats are also provided to the system in the form of data files which are used by small, generic message format processing subroutines. As discussed above the use of chains, sets and groups should be handled by independent data files and subroutines, however, in the demonstration system these syntax elements are handled at the message level. Effectively, the current implementation can very rapidly provide a new message format by replication and modification of existing data files, without modification of the existing software. In addition, message formats can be modified without any impact on the existing software.

4.4.5 Data Files for System Configuration. Although not unusual within a system, the demonstration system overall functionality is driven by indicators stored in configuration data files. Data such as which messages to generate based on the changed information, the activation of protocol-to-protocol allowed transformations, and the generation of free-text messages for unused information are all driven by data files. In this way the demonstration system can be configured as a receive-only system and incrementally configured until it has its full functionality.

4.5 Sample 1 Demonstration Input/Output. For this sample the demonstration system was configured to provide total protocol conversion, including USMTF and System output based on USMTF input. When comparing the USMTF input message and USMTF generated output message, note the difference in the "EMLOC" and "PRM" units-of-measure. This is a result of the standardization of the information base to set units of measure. The output units-of-measure could be configured to any logical set based on the operators needs thereby providing a consistent interface. Also note that the USMTF "EXER" and "COLLINFO" data is not transmitted via the MTS generated messages. This is a protocol related restriction, as the MTS protocol provides no capability to exchange this type of information (it may exist in other MTS messages not implemented in the demonstration model).

Input USMTF "C121 - TACELINT" Message #24 Created and Received:

```
OPFAC_2
0000024
UNCLAS
EXER/DLIS DEMONSTRATION/SCENARIO 1.1//
MSGID/TACELINT/OPFAC_2/0000024/MAY//
COLLINFO/-/-/-/DLIS//
SOI/A0001/010614Z/010715Z/ABCD/EMITTER ONE/IZ/S9876EZ123499/ENEMY
 UNIT ONE/SCUD/GM//
EMLOC/-/P/UT:16TCC09509763/-/359.9G/1.4KM/800M//
PRM/-/98.7MHZ/D/-/F/PD:123.000/TRCK/-/VERT//
```

MTS "K403 - Tactical Elint Report (Intell Ops) Message #84 Generated and Transmitted:

```
-- Bit Coded Transmission --
(-- Left is First Bit of Transmission --)
1000000000010000000100100000010000101100010011000010110001000000001
0000000100000000010000000100000001000000001110101100110000011011001
1110010101101100111011111001000101101101000000110100000110000001
1000000011000111111110110110110000101100111000110111101101101010010
1011111001000111110011001011011000000010100000011100000011001111001
1010010011000101011100101010110100001001001100100001100111101000l
0111111111100100110010110111001100010100100001000000100011010010l
1110001111010001110111001011010001011011000101001101010001110011O
1001001000010101010000010011111000010111111111010101101100001110O
101011100100011111111110100101O

-- MTS Message Decoded --
00000001/084/ROUTINE/UNCLASSIFIED/0000/DLIS HOST/OPFAC-1/
OPFAC-3/ODD PARITY/
NO REPLY/RESPONSE REQUIRED/K403/9105230115Z/
A0001/9105010715Z/9105010715Z/ABCD/EMITTER ONE/IZ/9876EZ1234/99/
ENEMY UNIT ONE/SCUD/GUIDED MISSILE
```

MTS "K404 - Tactical Elint Report (Emitter Location)" Message #85 Generated and Transmitted:

(-- Left is First Bit of Transmission --)
10000000000100000001101000001000010110001001100001011000100000001
00000001000000001000000010000000100000001110101100110000011011001
100101010110110011101111100100010110110100000011010000001100000001
10000000110001111111100010001001010101110000100110000010100101001
1100101111100111101011000010000000100101010000100011100010011

-- MTS Message Decoded --
00000001/085/ROUTINE/UNCLASSIFIED/0000/DLIS HOST/OPFAC-1/
OPFAC-3/ODD PARITY/
NO REPLY/RESPONSE REQUIRED/K404/9105230115Z/
A0001/ELLIPTICAL AREA OF PROB. "ELP/EAP"/16TCC0950097630/
0080001400356

MTS "K405 - Tactical Elint (Parametric Data)" Message #88 Generated and Transmitted:

(-- Left is First Bit of Transmission --)
100000000001000000001000100001000010110001001100001011000100000001
00000001000000001000000010000000100000001110101100110000011011001
110101010110110011101111100100010110110100000011010000001100000001
1000000011000111111110010011100100011110000100001111001000001011
0100011110001110000011000001111001000000000

-- MTS Message Decoded --
00000001/088/ROUTINE/UNCLASSIFIED/0000/DLIS HOST/OPFAC-1/
OPFAC-3/ODD PARITY/
NO REPLY/RESPONSE REQUIRED/K405/9105230115Z/
A0001/98700000/DISCRETE FREQUENCY/
FREQ. MODULATED CARRIER (NONPULSED)/123/
TRACKING (OTHER THAN CONICAL/LOBE)/LINEAR VERTICAL

USMTF "C121 - TACELINT" Message #93 Generated and Transmitted:

DLIS HOST
0000093
UNCLAS
EXER/DLIS DEMONSTRATION/SCENARIO 1.1//
MSGID/TACELINT/DLIS HOST/0000093/MAY//
COLLINFO/-/-/-/DLIS//
SOI/A0001/010614Z/010715Z/ABCD/EMITTER ONE/IZ/S9876EZ123499/ENEMY
UNIT ONE/SCUD/GM//
EMLOC/-/P/UT:16TCC09509763/-/356.7T/1400M/800M//
PRM/-/98700000HZ/D/-/F/PD:123.000/TRCK/-/VERT//

GENERIC SYSTEM Entity Information Generated and Transmitted:

```
(*** indicates entity changes since last report)
--------------------------------------
     ORIGINATOR  OPFAC-2
     SSN  0000024
     MSG_DTG  9105230115Z
     IDENTIFIER  1002
***  EFF_DTG  9105010715Z
--------------------------------------
     IDENTIFIER  1002
***  LOC_TYPE  ELLIPSE
***  START_DTG  9105010614Z
***  STOP_DTG  9105010715Z
***  EMIT_DESIG  EMITTER ONE
***  INTENT  ENEMY
***  LOC_CAT  ELLIPTICAL AREA OF PROB. "ELP/EAP"
***  CTRY_SIGHT  IZ
***  TYPE  OTHER
***  UNIT_DESGN  ENEMY UNIT ONE
***  SIGNAL_ID  A0001
***  ELINT_SORT  ABCD
***  ID_BE  9876EZ1234
***  BE_SUFFIX  99
***  WEAPONS  SCUD
***  EMIT_FUNC  GUIDED MISSILE
***  FREQUENCY  98700000 HZ
***  RF_MODE  DISCRETE FREQUENCY
***  PRIACTYCOD  FREQ. MODULATED CARRIER (NONPULSED)
***  PULSE_DURA  123 uSec
***  SCAN_TYPE  TRACKING (OTHER THAN CONICAL/LOBE)
***  ANT_POLAR  LINEAR VERTICAL
***  COLL_PRJNM  DLIS
--------------------------------------
     IDENTIFIER  1002
***  REL_LOC  16TCC0950097630
***  BEARING  356.7 True
***  MAJOR_AXIS  1400 Meters
***  MINOR_AXIS  800 Meters
***  ELLIPSE  800/1400/356.7
--------------------------------------
-- MESSAGE REFERENCE --
     ORIGINATOR  OPFAC-2
     SSN  0000024
     MSG_DTG  9105230245Z
     SOURCE  MTF
     SECURITY  UNCLASSIFIED
     MSG_NUMBER  C121
     REPORT_DTG  9105230245Z
     COMMENTS  TARGET TYPE: SIGNAL IDENTIFIER
     TITLE  C121 - TACELINT
```

MSG_MONTH MAY
EXERCISE DLIS DEMONSTRATION
EXER_ID SCENARIO 1.1

-- NEW MESSAGE RECEIVED --
ORIGINATOR OPFAC-2
SSN 0000024
MSG_DTG 9105230115Z
SOURCE MTF
SECURITY UNCLASSIFIED
MSG_NUMBER C121
REPORT_DTG 9105230115Z
COMMENTS TARGET TYPE: SIGNAL IDENTIFIER
TITLE C121 - TACELINT
MSG_MONTH MAY
EXERCISE DLIS DEMONSTRATION
EXER_ID SCENARIO 1.1

4.6 Sample 2 Demonstration Input/Output. For this sample the demonstration system was also configured to provide maximum protocol output. Note that although the only new information received in the MTS message was the emitters fixed location, the messages generated provided additional data based on the information contained in the information base on emitter A0001. In the Generic System information generated, it is anticipated that the host would only be provided the "***" data and the necessary data to identify the entity. Of particular note is the generation of the MTS K446 - Enemy Sighting (SPOT) Report. This report is generated when the emitter location becomes fixed.

Input MTS "K404 - Tactical Elint Report (Emitter Location)" Message #31 Created and Received:

(-- Left is First Bit of Transmission --)
1000000011000000111010000000100010000000100000001000000010110001
00110000101100001110100100110000011011001100101010110110011101100
0001100101101001000000110100000110000000110000000110001111111000
10000001010101110000100110000110100101100111111111110001111110000
0000

-- MTS Message Decoded --
00000001/031/PRIORITY/UNCLASSIFIED/0000/OPFAC-1/DLIS HOST/
EVEN PARITY/
NO REPLY/RESPONSE REQUIRED/K404/91052303002/
A0001/EMITTER LOCATION "FIX"/16TCC0972198300

USMTF "C121 - TACELINT" Message #96 Generated and Transmitted:

DLIS HOST
0000096
UNCLAS
MSGID/TACELINT/DLIS HOST/0000096//
COLLINFO/-/-/-/DLIS//
SOI/A0001/010614Z/010715Z/-/EMITTER ONE/-/-/-/SCUD/GM//
EMLOC/-/F/UT:16TCC09729830//
PRM/-/98700000HZ/D/-/F/PD:123.000/TRCK/-/VERT//

MTS "K404 - Tactical Elint Report (Emitter Location)" Message #96 Generated and Transmitted:

(-- Left is First Bit of Transmission --)
10000000100100001110110000001000010110001001100001011000010000000
10000000100000001110101100110000011011001100101010110110011101100
0001100101101001000000110100000110000000110000000110001111111000
10000001010101110000100110000110100101100111111111110001111110000
0000

```
-- MTS Message Decoded --
00000001/096/PRIORITY/UNCLASSIFIED/0000/DLIS HOST/OPFAC-3/
ODD PARITY/
NO REPLY/RESPONSE REQUIRED/K404/9105230300Z/
A0001/EMITTER LOCATION "FIX"/16TCC0972198300
```

MTS "K446 - Enemy Sighting (SPOT) Report" Message #97 Generated and Transmitted:

```
(-- Left is First Bit of Transmission --)
10000000100100001110001000001000010110001001100001011000010000000
```

```
-- MTS Message Decoded --
00000001/097/PRIORITY/UNCLASSIFIED/0000/DLIS HOST/OPFAC-3/
ODD PARITY/
NO REPLY/RESPONSE REQUIRED/K446/9105230300Z/
K404 - TAC ELINT (EMITTER/9105230300Z/OTHER/16TCC0972098300/
9105230300Z/ENEMY UNIT ONE/
```

GENERIC SYSTEM Entity Information Generated and Transmitted:

```
(*** indicates entity changes since last report)
--------------------------------------
     ORIGINATOR  OPFAC-1
     SSN  031
     MSG_DTG  9105230300Z
     IDENTIFIER  1002
***  EFF_DTG  9105230300Z
***  LOCATION  16TCC0972198300
--------------------------------------
     IDENTIFIER  1002
***  LOC_TYPE  POINT
     START_DTG  9105010614Z
     STOP_DTG  9105010715Z
     EMIT_DESIG  EMITTER ONE
     INTENT  ENEMY
***  LOC_CAT  EMITTER LOCATION "FIX"
     CTRY_SIGHT  IZ
     TYPE  OTHER
     UNIT_DESGN  ENEMY UNIT ONE
     SIGNAL_ID  A0001
     ELINT_SORT  ABCD
     ID_BE  9876EZ1234
     BE_SUFFIX  99
```

```
     WEAPONS  SCUD
     EMIT_FUNC  GUIDED MISSILE
     FREQUENCY  98700000 HZ
     RF_MODE  DISCRETE FREQUENCY
     PRIACTYCOD  FREQ. MODULATED CARRIER (NONPULSED)
     PULSE_DURA  123 uSec
     SCAN_TYPE  TRACKING (OTHER THAN CONICAL/LOBE)
     ANT_POLAR  LINEAR VERTICAL
     COLL_PRJNM  DLIS
--------------------------------------
-- MESSAGE REFERENCE --
     ORIGINATOR  OPFAC-1
     SSN  031
     MSG_DTG  9105230300Z
     SOURCE  MTS
     PRECEDENCE  PRIORITY
     SECURITY  UNCLASSIFIED
     MSG_NUMBER  K404
     REPORT_DTG  9105230300Z
     TITLE  K404 - TAC ELINT (EMITTER LOCATION)
     RCPT_COMP  NO REPLY/RESPONSE REQUIRED
--------------------------------------
-- NEW MESSAGE RECEIVED --
ORIGINATOR  OPFAC-1
SSN  031
MSG_DTG  9105230300Z
SOURCE  MTS
PRECEDENCE  PRIORITY
SECURITY  UNCLASSIFIED
MSG_NUMBER  K404
REPORT_DTG  9105230300Z
TITLE  K404 - TAC ELINT (EMITTER LOCATION)
RCPT_COMP  NO REPLY/RESPONSE REQUIRED
```

5. SUMMARY

5.1 Feasibility. The development and fielding of a Data Link Interface System that would provide a modular, reusable host interface into multiple digital data link protocols is completely feasible and economical using existing technology. The system as hypothesized and discussed in section 2 is largely based on the reuse of current technology for lower layer functionality and a totally software/data driven Application Layer. As the lower layers are already implemented in current systems, their technical feasibility is fundamental. The software/data driven Application Layer, as discussed in section 2, physically demonstrated in the DLIS model and documented in section 4, soundly proves the technical feasibility of this system.

5.2 Adaptability and Maintainability. As discussed in sections 2 and 4, and demonstrated in the model, the concept of interfacing multiple protocols at the Application Layer of the reference model is the only economically feasible method of satisfying the Data Link Interface System requirement. If the development of this system properly uses data driven processes to the maximum extent and places the highest priority on adaptability and maintainability, the Data Link Interface System has the capability to resolve most of the interoperability problems experienced today. The additional use of POSIX and Ada standardization would also increase the systems overall cost savings and maintainability. As presented in the Data Link Interface System concept, the modification of one protocol shouldn't necessarily require the modification of the information base and the other interfaced protocol implementations. The modification of the DLIS information base should only result from the modification or addition of information in relation to the "real-world". To this end, the Data Link Interface System should be developed with the maximum amount of "real-world" user involvement as possible. For this reason an evolutionary development approach is recommended, to provide this constant user involvement, and repetitive validation of the understanding of the information.

6. CONCLUSION

6.1 Feasible. Based on the results of this feasibility analysis, the realization of the hypothesized Data Link Interface System is within the scope of existing technology, is cost effective, and has the potential of resolving most of the existing interoperability problems.

7. RECOMMENDATIONS

7.1 Continued Development. It is recommended that the development of this Data Link Interface System continue as rapidly as possible. This development should be based on an evolutionary development strategy to provide maximum involvement of the user community. The next phase of development should be the development of a brass board configuration that can further provide best-practice answers for the full-scale development of the system.

7.2 Standing Working Group. The development and follow-on upgrades of the Data Link Interface System is going to require the continuous participation of users of the system information and individuals experienced in the configuration management processes of the many different protocols. It is recommended that a standing working group of experienced users and protocol experts be formed to provide guidance/answers to many of the questions that are going to be produced by this development. The successful development of the Data Link Interface System is greatly dependent upon the understanding of the "real-world" information as exchanged by the data in each interfaced protocol. This understanding of the information (what does it mean) can only be found in current, experienced operational personnel. In addition, the protocol experts are needed to provide information as to why the syntax of the protocols (messages, groups, etc.) are implemented the way they are, and if found to be in error, the proper procedures to initiate the resolution of the problem in the most expeditious manner.